

Integrating computational thinking into English writing: development of a computational thinking-integrated module

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ABSTRACT

This study addresses challenges in teaching English writing skills in English as a second language (ESL) classrooms, proposing a novel approach through computational thinking (CT). A CT-integrated writing module was developed for primary school ESL teachers using the analysis, design, development, implementation, and evaluation (ADDIE) model and qualitative research. Incorporating constructivist and experiential learning theories, the module uses visualization tools like circle maps and flow maps across 8 units, combined with an inquiry-based approach, scaffolding, and localized materials. The 5 CT elements-decomposition, pattern recognition, abstraction, algorithmic thinking and logical reasoning-are embedded to enhance learning. Focus group interviews with 4 ESL experts indicate strong acceptance, highlighting the module's usability, content, and teaching activities. The study provides a framework for CT-based instructional modules to improve problem-solving and cooperative learning in English writing education.

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1. INTRODUCTION

This study investigates the effects of integrating computational thinking (CT) into language learning, specifically within primary English as a second language (ESL) education. While earlier studies have explored the impact of CT on areas such as text comprehension, vocabulary acquisition, and grammar visualization, they have not explicitly addressed its influence on problem-solving skills and language acquisition at the primary level.

Recent studies indicate promising outcomes when CT is integrated into language learning. For instance, Dong *et al.* [1] found that modeling and algorithms improve text comprehension and vocabulary acquisition. In a small-scale experiment, Syropoulos *et al.* [2] demonstrated CT's effectiveness in Greek language learning. At the same time, Hsu *et al.* [3] showed that programming with educational robots enhances CT skills and reduces language anxiety among Chinese and English learners. Additionally, Parsazadeh *et al.* [4] asserts that CT-based digital storytelling boosts motivation and performance in English learning. These findings suggest that CT enhances problem-solving skills and interactive learning in language education, moving beyond its traditional science, technology, engineering, and mathematics (STEM) applications.

However, despite the acknowledged potential of CT for problem-solving, its application in language lessons remains limited [1], [5] proposes that CT fits naturally into language arts and social studies, while Parsazadeh *et al.* [4] recommends its use to enhance English learning—a vital skill for 21st-century integration. Nonetheless, CT remains peripheral in foreign language instruction [6], with few studies combining CT and language learning [7]. Although the number of CT-related studies has increased, specific work at the primary school level is still in its infancy [8], [9]. Implementing CT also poses challenges; for instance, many Malaysian teachers have a low understanding of CT due to limited professional development opportunities [10]–[13].

This study integrates CT into an English writing module for year 5 primary school students to enhance teachers' pedagogical skills and student achievement. The module, grounded in constructivist theories, emphasizes student-centered, activity-based, and inquiry-based teaching using visualization diagrams. The research objectives are to: i) identify suitable CT elements for writing instruction; ii) determine effective CT teaching methods; iii) define the essential components of an English writing module; and iv) evaluate user acceptance of the developed module. The research questions are:

- Which CT elements are best suited for different types of writing in the module?
- What is the most effective CT teaching and learning methods for the English writing module?
- What are the key components of an English writing teaching module?
- How is user acceptance of the developed module evaluated?

2. LITERATURE REVIEW

In Malaysia, the Malaysian education blueprint (MEB) aims to develop thinking skills, prompted by the country's lagging performance in Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) assessments. The MEB emphasizes critical thinking, reasoning, creativity, and innovation, highlighting the need for improvements in applying knowledge and thinking critically beyond familiar contexts [14]. According to Shah *et al.* [15] the main challenges ESL learners face includes untrained teachers, ineffective teaching methods, low motivation, insufficient ideas, limited writing practice, and poor reading habits. Rashid *et al.* [16] points to similar issues, with teachers lacking appropriate methods, materials, and topics to assist in writing. Consequently, both mainstream and ESL teachers demand effective techniques to enhance writing skills [17]. The introduction of the English plus 1 textbook, aligned with Common European Framework of Reference for Languages (CEFR), has sparked debates among stakeholders, as it focuses more on global rather than local contexts [18], [19]. While Zaki and Darmi [20] argues that CEFR is not a strict teaching strategy, they call for research on how Malaysian ESL instructors can effectively integrate it, addressing classroom challenges for different skills. Saad and Zainudin [21] suggest focusing on how CT learning activities can improve instructional quality, emphasizing a need for a teacher's guide on CT implementation.

Scaffolding and inquiry are commonly recommended CT techniques, with visual tools dominating CT-based problem-based learning (PBL) approaches [21]. However, enhancing teaching practices remains a challenge due to insufficient context-specific support and professional development. Prior research suggests using visualization tools and local materials to teach CT.

CT enables the breakdown of complex problems into manageable solutions, fostering skills essential for conceptualizing, analyzing, and problem-solving [22]–[24]. Writing itself is a complex cognitive process requiring significant effort to structure language, which can benefit from CT's methodical approach [25]. Non-native English speakers need familiarity with writing processes and features like formality and complexity for accuracy [26], [27]. While English writing is often the most challenging skill to teach and acquire, CT integration offers a potential solution to improve both language and thinking skills concurrently.

3. METHOD

The study used the analysis, design, development, implementation, and evaluation (ADDIE) model as a framework to develop the English writing module, employing qualitative research with triangulation techniques such as interviews and document reviews.

3.1. Analysis

In the analysis phase, the study addressed challenges in learning writing and identified the need for instructional materials and CT approaches for primary pupils. This phase aimed to determine suitable CT elements for different writing types within the module. The analysis used a triangulation method that included a literature review, document review, and focus group discussions (FGD) using semi-structured interview questions with 4 experienced ESL educators. The document review, guided by a checklist instrument, covered key educational materials such as the Standards-Based English Language Curriculum (SBELC), Standard

Curriculum for Primary Schools (SCPS), year 5 Scheme of Work (SoW), and the English workbook, ensuring alignment with national standards. The module's integration with the CEFR ensured appropriate language proficiency levels for year 5 pupils. The semi-structured interview questions focused on 3 key areas: usability, asking how easy it is to implement the module in a typical year 5 classroom and the feasibility of integrating CT elements like decomposition and algorithmic thinking into writing lessons; content relevance, assessing the module's alignment with SBELC and the suitability of visual tools like circle maps and flow maps; and effectiveness, exploring student responses to CT-based writing activities and improvements in problem-solving skills. FGD were recorded, transcribed, and analyzed to gather in-depth feedback. Additionally, the document review employed a comparison table that systematically assessed existing materials to identify strengths and areas for improvement. This ensured that the module incorporated effective strategies for year 5 pupils. Integrating CT skills into the English writing module enhances students' problem-solving abilities and communication, promoting holistic language development.

3.2. Design

Following the analysis, a blueprint for the module was created, detailing its structure, content, activities, and assessments to integrate CT into writing tasks. Appropriate instructional strategies and materials were designed for each topic, and visualized through a storyboard to align with learning objectives. Steps for CT integration included:

- Analyze task: identify the main processes in writing tasks.
- Consider problem-solving: determine CT steps like extracting information, decomposition, algorithm formulation, and solution design.
- Identify local resources: use context-relevant materials for CT integration.
- Propose hands-on activities: engage students in CT through writing tasks.
- Choose visualization diagrams: aid understanding of tasks and CT processes.
- Apply inquiry techniques: encourage exploration using who, what, when, where, why, how (5W1H) to integrate CT concepts.

3.3. Development

Transitioning from design to development, the module was constructed based on conceptualized ideas and design principles. Prototypes emphasized a CT approach with hands-on, inquiry-based, student-centered activities. Key CT elements such as decomposition, pattern recognition, abstraction and algorithms were integrated. The modules underwent expert validation by 2 lecturers and 2 experienced English teachers, providing feedback to enhance examples, activities, and content coherence. Revisions were made based on this feedback to ensure quality and effectiveness.

3.4. Implementation

The module was then implemented by year 5 English teachers, who facilitated self-paced learning in their classrooms. A WhatsApp group served as a support channel for teachers to engage with the module's structure, content, and strategies, allowing them to tailor materials to their classroom needs. Teachers not only facilitated the module but also evaluated its real-world effectiveness, gathering insights into its strengths and areas for improvement. These observations were fundamental for the subsequent evaluation phase.

3.5. Evaluation

The final phase evaluated the module to measure its impact on outcomes. This formative evaluation included a focus group interview with primary TESL teachers to thoroughly assess the module's integration of CT. The 4 English instructors, referred to as teachers A, B, C, and D, participated in the focus group, providing valuable feedback to guide future refinements and iterations of the module. The instrument used for the evaluation consisted of the developed module and a set of semi-structured interview questions focusing on the module's suitability for English learning, its integration of the CT approach, and overall user satisfaction.

4. RESULTS AND DISCUSSION

This section outlines the research findings in 2 parts: module development and evaluation. The development segment details the process of incorporating suitable CT elements into the English writing module. The evaluation part assesses user acceptance of the module, addressing all research objectives and their outcomes.

This study introduces a novel approach by integrating CT elements into English writing instruction, which has not been previously explored in the context of primary ESL education. Unlike traditional writing modules, this research uniquely applies CT skills like decomposition and pattern recognition, offering fresh

insights into enhancing problem-solving in language learning. Additionally, the incorporation of visualization tools (such as circle maps and flow maps) to support writing, an inquiry-based learning approach, and localized materials tailored to the students' environment adds further innovation. These findings address long-standing challenges in improving students' analytical skills in writing by providing a new framework that blends language learning with critical thinking. Moreover, CT integration in writing improves students' ability to break down complex tasks, a previously unaddressed area in ESL education, fostering a deeper understanding of both language and problem-solving.

4.1. Module development

The components of the module are thoroughly explained with regard to the overall structure of the English writing module, covering various topics and subtopics that it includes. In particular, special attention is given to the integration of the CT approach, highlighting how it is embedded throughout the module to enhance students' analytical and reasoning skills as they develop their English writing abilities.

4.1.1. Components of the English writing module

The module comprises 9 key components: theme, topic, content standard, learning standard, learning objective, CT element, inquiry, and visual diagrams. These components, derived from the SBELC, SoW, and "English plus 1 (student's book) year 5," facilitate engaging learning activities.

4.1.2. Topics of the module and the CT elements

Aligned with the CEFR and SBELC, the module includes 8 units covering 8 themes from the year 5 English textbook: yourself, towns and cities, wildlife, days, learning world, food and health, sport, growing up and going away. Each topic uses different CT elements tailored to the writing genre. Literature and thematic analysis identified 5 CT elements suitable for integration: decomposition, algorithms, pattern recognition, logical reasoning, and abstraction. These elements are introduced at the module's start to aid teacher comprehension. Each writing style uses specific CT elements, with relevant diagrams provided.

- Abstraction focuses on identifying key problems and concepts in writing tasks. For instance, a unit on "food and health" would focus on producing a menu rather than exploring diverse foods.
- Decomposition is applied in all units, breaking tasks into manageable subtasks using the 5W1H framework, integrating inquiry-based techniques.

Table 1 outlines the CT approach implemented across the 8 units, emphasizing student-centred, activity-based, and inquiry-based teaching, as recommended by Saad [28]. Additionally, visual diagrams are used as tools to support learning and enhance understanding [29], [30].

Table 1. CT approaches across the 8 units

Unit	Writing media	Type	Inquiry	Visualisation- diagram
Unit 1 town and city	Description of town/city	Abstraction decomposition algorithm	(Core: open-ended driving questions) > discussion > activity summary board	Bubble map
Unit 2 days	Description of a celebration or special day	Decomposition pattern recognition abstraction	5W1H	Flow chart
Unit 3 wildlife	Leaflet	Decomposition pattern recognition	5W1H	Bubble double map fish bone diagram or multi-flow map
Unit 4 learning world	Email	Decomposition algorithm	5W1H	Tree map
Unit 5 food and health	Blog	Pattern recognition abstraction algorithm	5W1H	Flow chart/activity diagram
Unit 6 sport	A profile of a sports star	Pattern recognition Abstraction	5W1H	Table
Unit 7 growing up	Biographical questions and answers for the magazine	Algorithm pattern recognition	5W1H	Bubble map
Unit 8 going away	Writing an email about a friend's visit	Abstraction, logical reasoning and algorithm	5W1H	Activity diagram/flowchart

Pattern recognition was used to identify similarities between current and prior situations, aiding in selecting suitable grammar for various writing genres. Each genre requires a distinct style, and previous examples help guide similar writing tasks. Pupils must apply syntax and grammar rules to construct cohesive sentences, enhancing their understanding of sentence patterns and improving their writing skills.

Algorithms involve step-by-step instructions for solving a problem. Sequencing is crucial in certain writing tasks, particularly when detailing processes or tasks using logical steps. For instance, in unit 5 ("food and health"), algorithms guide writing about the process of cooking a "favorite meal". In unit 8 ("going away"),

they help outline the sequence of a trip to Pulau Langkawi. Pupils also learn to use appropriate sequence connectors, with visual aids like flowcharts or activity diagrams supporting the process.

4.1.3. Visualisation diagram to support writing

Various diagrams were employed to support visualization across different writing styles, consistent with previous studies on CT in instruction. These diagrams fall under 2 categories: I-Think Maps and unified modeling language (UML), featuring 8 types: circle maps, bubble maps, tree maps, bracket maps, flow maps, multi-flow maps, fishbone diagrams, and activity diagrams. Bubble maps were used extensively for 5W1H questioning to generate ideas for topics. Figure 1 shows a bubble map example from unit 1, “town and city,” which can be adapted to other topics.



Figure 1. Bubble map

Tree maps organize information into categories and are used in unit 4, “learning world,” to outline the content flow of an email. The teacher uses the map to depict each content block. Figure 2 illustrates a double bubble map from unit 3, “wildlife,” which compares similarities and differences between animals. Additionally, the fishbone diagram helps represent factors influencing animal extinction, and the multi-flow map can be utilized similarly. Guidance is provided for teachers on how to use these diagrams effectively.

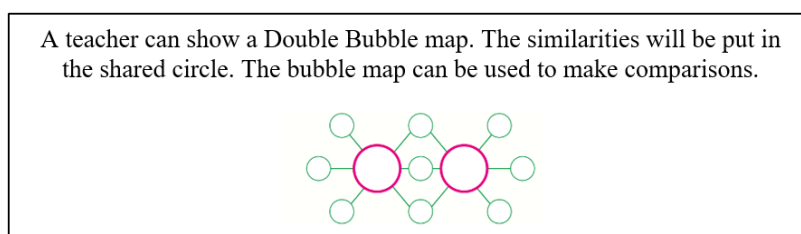


Figure 2. Double bubble map

4.1.4. Inquiry-based learning

Inquiry-based learning, a key CT approach, encourages problem-solving through high-level questioning, allowing active participation from both students and instructors [31]. This module heavily uses the 5W1H questioning method to explore issues and scenarios from various perspectives.

4.1.5. Localised materials

Adapting teaching to local contexts does not limit its broader applicability [32]. Effective localized materials consider shared realities across different settings [33], making CT learning culturally relevant. Saad and Zainudin [34] further highlight localized examples as essential for cooperative, project-based learning. Most units in the module use local context. For example, unit 1 “town and city” includes Malaysian cities like Kuala Lumpur and Kuching. Unit 2 “days” features national celebrations like national day and Eid al-Fitr. Unit 3 uses a popular Malaysian blog “health and food.” Units 5 and 6 reference Malaysian celebrities like Siti Nurhaliza and sports star Lee Chong Wei.

4.1.6. Learning theories

Integrating theory ensures effective pedagogical practice, with the module drawing on constructivist learning principles to promote active, task-centered participation. It aligns with learning theories such as constructivism, Kolb's experiential learning, and social constructivism, all emphasizing student engagement and knowledge construction [35]. Constructivist elements are embedded in the instructional design, using inquiry techniques and diagram construction to foster hands-on, experiential learning. This approach aligns with Chiu [36], affirming that exploration builds comprehension. The experiential learning theory emphasizes active student involvement and reflection, fostering deeper cognitive understanding [37].

4.2. Evaluation

The evaluation involved 4 year 5 English teachers and one English lecturer from the Institute of Teacher Education (IPGM), all with over 5 years of teaching experience. Respondents A, B, C, and D had 15, 20, 13, and 8 years of experience, respectively, teaching in both rural and urban settings. A 1-hour interview was conducted via Google Meet, and participants reviewed the module 2 weeks prior. Semi-structured interviews covered 3 topics: module suitability for English learning, CT approach, and overall satisfaction, with responses analyzed thematically.

4.2.1. Module suitability for English learning

Feedback was positive, with respondent A describing the module as "good and interesting," while respondent D noted its helpfulness for integrating CT into year 5 English teaching. Respondent C praised the module's alignment with CT and language learning, emphasizing its importance for developing critical thinking and problem-solving skills early on. Feedback from respondent B was similarly positive, highlighting the module's practicality and relevance to classroom application. Additionally, respondent B appreciated the balance between theory and hands-on activities, stating that it allowed them to understand not only what CT is but also how to implement it effectively.

4.2.2. Contents

Respondent A finds the module effectively covers writing skills with well-explained ideas. All respondents agree that the content is engaging and easy to follow, though there are differing views on learning activities. Teachers A and D recommend simplifying by using one diagram (either a bubble map or 5W1H table) in module 1, while teacher C suggests integrating both seamlessly.

All agree the module includes essential information for teachers and pupils but may need additional depth for student comprehension. The 2 respondents find the content easily understandable, but there is a suggestion to provide more in-depth instructions and specific guidelines for teachers without an English background. Additional training for effective module implementation is recommended.

According to all respondents, the module is aligned with learning objectives and curriculum standards (SBELC, SoW, student activity books). Its content is logically organized, and activities effectively support the "think and plan" step in the English year 5 writing guide, deemed critical for writing progression. Teachers believe the module helps students learn both writing and CT skills indirectly. Respondent D emphasizes that the module encourages practice, creative thinking, and innovative development, aligning with Saad and Zainudin [34] and Kong [35] on fostering critical thinking and problem-solving skills (HOTS), essential for academic and workforce success.

4.2.3. Localised materials

Respondents supported the use of localized content before introducing international examples, enhancing student comprehension and engagement. The module's activities were deemed appropriate and feasible. Respondent B praised the integration of local materials for engaging students while maintaining flexibility with international examples. This scaffolding approach guides students from initial activities to writing tasks.

4.2.4. Multiple intelligence and pupils' abilities

While the module aligns with students' developmental needs, respondents C and D suggested incorporating multiple intelligence strategies to cater to visual, auditory, reading/writing, and kinaesthetic learners. Teacher D noted activities like gallery walks could appeal to kinaesthetic learners. Respondent A mentioned that using post-it notes increases student participation and motivation. Diagrams support visual learners, and the module is seen as suitable for high-ability and mixed-ability classes, with a recommendation for group work to support diverse skill levels.

4.2.5. Scaffolding and inquiry

Teachers observed that the module uses scaffolding techniques to support learning, encouraging active participation through inquiry-based methods. Tools like diagrams and models help students better understand and engage with the content. Teacher B highlighted how these teaching aids make scaffolding more effective, while respondent C noted that the inquiry approach fosters creative thinking and student participation by posing thought-provoking questions, aligning well with CT principles.

4.2.6. Overall suggestions

The final questions derive to sought suggestions for future improvement from the 4 responses. Response from respondent A: “perhaps can add more interesting activities to enrich the student’s understanding of the lesson and the techniques as well.” Respondent B suggests grammar and sentence form while completing the writing job. The typeface in the table taken from the textbook is quite small. Perhaps it can be made larger so that it is readable.

Respondent C provided a more precise suggestion. “I would like to propose that the complementary content standard, learning standard, and learning objective be included for each learning standard. This is due to the fact that one skill helps the other. It is used in formative assessment or in-class assessment (PBD). Throughout the language lessons from units 1 to 8, each learning standard can be tested”. He added that “more elaboration and notes can be given to the teachers, especially on the language functions and grammar rules. Not all who teach English are English major teachers. Those who are having difficulty learning the language would benefit from a bottom-up approach. Differentiated learning tactics can also be given in the module for teachers to cater to students of different levels.”

Future module development should enhance grammar instruction by integrating specific tasks in each unit, progressing from word formation to phrases, sentences, and paragraphs. This approach would build writing skills and grammar mastery simultaneously. Misrom *et al.* [38] suggest leveraging technology for 2-way learning. Developing a mobile app or e-module would be valuable that would address the technological, pedagogical, and psychological dimensions of inclusive learning is recommended [39], [40]. This aligns with Khlaisang and Sukavatee [41], emphasizing that mobile applications and virtual learning support English skill development in flexible, interactive settings. Incorporating gamification elements, such as points and rewards, could boost English learning outcomes [42], [43] note that gamification enhances interest and motivation in students, particularly for vocabulary learning. Adding these elements could make the writing module more engaging and effective.

Training teachers on CT and its integration within the module is crucial, as many are familiar with CT but unclear on its application in teaching, particularly in writing instruction. Future research should consider CT-based modules for reading, listening, and speaking, as Karataş and Tuncer [44] highlights the importance of integrating all 4 language skills. Developing modules for each skill can enhance comprehensive language proficiency. A needs analysis survey is recommended to ensure that modules are tailored to learners’ needs and contexts, improving relevance and effectiveness [44]. The module evaluation should focus on multiple aspects:

- Writing competency: assessing students’ skills in idea expression, coherence, grammar, vocabulary, and quality.
- Problem-solving skills: evaluating students’ abilities to analyze and resolve challenges during writing tasks, fostering critical thinking.
- Motivation and achievement: observing student engagement, participation, and alignment with learning outcomes.
- Teacher motivation: gauging teacher engagement, commitment, and perceived module impact.

This comprehensive evaluation will help educators refine teaching practices and enhance the module to better serve both students and teachers.

5. CONCLUSION

This study developed and evaluated a CT-integrated English writing module for primary school ESL teachers, addressing previous challenges. Using the ADDIE model and constructivist and experiential learning theories, the module provides a structured, task-centered approach, focusing on guiding teachers in teaching writing, especially section B: “think and plan.” It helps students brainstorm using the 5W1H technique, organize ideas visually, and structure paragraphs effectively. Key CT elements like decomposition, pattern recognition, and algorithmic thinking foster critical problem-solving skills, aiding in grammar selection and idea organization. The module aligns with constructivist principles, enhancing both CT and writing skills, and potentially improving performance in international assessments like TIMSS and PISA. By localizing materials and incorporating CT, the module not only benefits primary ESL students but also offers a scalable model for integrating problem-solving skills into language education, potentially influencing curriculum development at a larger scale.

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C : **C**onceptualization

M : **M**ethodology

So : **S**oftware

Va : **V**alidation

Fo : **F**ormal analysis

I : **I**nvestigation

R : **R**esources

D : **D**ata Curation

O : Writing - **O**riginal Draft

E : Writing - Review & **E**ding

Vi : **V**isualization

Su : **S**upervision

P : **P**roject administration

Fu : **F**unding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author, [AS], upon reasonable request.

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